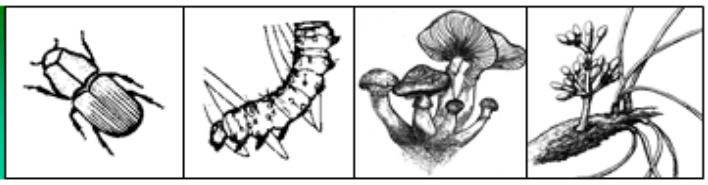
Forest Health Protection



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Region 4 Cumulative Insect Impact Estimation 1991-2015

INTERMOUNTAIN REGION R4-FHP-19-01

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Abstract

Large-scale insect-caused tree mortality and defoliation events can impact resource management. These insect outbreaks can disrupt ecosystem functions and services and change elements of the biological and/or physical environment. Aerial detection survey (ADS), conducted by Forest Health Protection (FHP) specialists, captures insect-caused tree mortality and defoliation, during annual flight missions. This observational data can be used as a guide in management and planning. However, without well-developed tools and an understanding of the history of the data collection, issues can arise with misuse of data. Aerial detection survey data has nuances that need to be considered for appropriate use. For example, combining multiple years of data may overestimate the area impacted by counting the same acre or tree multiple times across years. The objective of this exercise was to develop products and tools for use by Region 4 resource managers and to summarize several of the major forest insects that have impacted Region 4 forests. The USDA Forest Service Region 1 Cumulative Impact Tool (Egan 2018 and NRGG 2016) was the source for this project and was adopted for Region 4. The outputs from this tool were applied to create historical GIS-based products illustrating the cumulative impacts of several insects across the Intermountain Region from 1991-2015. Users should contact Information Management and their respective Forest Health Protection field office with questions.

Objective

The objective of this exercise was to estimate cumulative impacts of several major forest insect events that have occurred in Region 4 and to develop useful products for use by Region 4 resource managers. Aerial detection survey data users are advised not to sum consecutive years of ADS data. This often results in counting the same acres multiple times and over-estimating the total area of impact. In order to make ADS data functional for estimating cumulative impacts (i.e. offering a sum of acres and/or trees impacted), Northern Region Geospatial Group (2016) and Egan (2018) have developed a tool that accounts for several limitations of the ADS dataset. We have collaboratively utilized this tool to develop products that are intended to take older (1991-2015) ADS data and offer a best available estimate of historic cumulative impacts in Region 4. The imbedded maps, discussion on methodology and ADS history offers a description of the dataset, methodology, and products herein. These products are intended to inform and assist managers. Because these products and the tool outputs rely on ADS data, they should not be used as a replacement for field-level surveys. Final layer locations and guidance on

clipping and geoprocessing are included to assist users in accessing the products and developing project-specific estimations of cumulative historical impacts. Appendices include critical information regarding guidance on the appropriate and inappropriate use of the tool outputs for each biotic agent.

Region 4 Aerial Detection Survey

A vast majority of the national insect and disease detection survey database consists of ADS data. Data that aerial surveyors collect is observational. Surveyors collect data based on trees visibly affected by forest insects and diseases, which are recorded on digital sketch maps (2016-present) during aerial flights. Surveyors are flying at 80 to 120 knots (92-138 miles per hour) across the landscape. In a short time, the surveyor must: identify the damage; classify the type of damage (mortality, defoliation, etc.); identify the tree species; determine a likely causal agent; make an estimate of intensity; decide how to capture the damage on an electronic sketch mapping system; locate and draw the damage area on the moving map display; and, attribute the point or polygon appropriately.

Surveyors use two types of flight patterns to map forest damage – contour and grid. Grid flights may be a more efficient method of flying most forested lands. Contour flights provide a more in-depth observation of the landscape. Current standard procedures for grid flight patterns are to offset grid lines every 3 miles (2 surveyors covering 1.5 miles out each side of the aircraft) and align the flight grids in parallel to major mountain ranges as much as possible In areas of high mortality or defoliation, a 2-mile grid pattern may be utilized to more effectively map infested areas, but this technique is rarely used in Region 4 and not likely to be used in the future due to emphasis to cover maximum acres in a given survey year.

Since 2008, Region 4 has moved from nearly 100% contour flight patterns to approximately 95% grid flight patterns. This has reduced average flight hours per year dropping by about 1% from 995 hours/season to 981 hour/season, and it has allowed an increase in coverage area by approximately 7% (69.3 million to 74.3 million). Once flights have been completed, R1/4's ADS coordinator, aerial surveyors, entomologists, pathologists, and the FHP GIS specialists process data to identify, correct and update coding errors. Entomologists, pathologists, technicians and aerial surveyors will complete ground checks of data as time and direction allows, however time and staff restrictions result in only several days of ground checks each year and the level of checks varies.

Region 4 Aerial Detection Survey and Data Distribution History

The first aerial detection flights for insect damage were in the 1930s. These were specific flights to document mountain pine beetle impacts near Yellowstone. Other tree damage was also noted and surveys were broadened in scope to capture more damage agents, after these early years proved beneficial to delineating impacted areas from additional insect disturbances. Up through the 1980s, special surveys to capture certain pest events were the main survey types. Maps were either given to the National Forests or hand copies were made and provided to management teams for use.

In the 1970s, general overview surveys were conducted to create a "snap shot" of the year across large areas. The purpose of the general survey was to capture as much disturbance since the previous survey for a given area. Through the 1970s, various paper map formats were used and depending upon the scale the surveyor planned to cover would dictate which maps to use. Generally 1:100,000, 1:126,720 or 1:250,000 were the preferred map sizes. By the 1990s overview surveys were being conducted for most of the forest land in Region 4, however some areas were only surveyed every other year, and wilderness areas and non-timber emphasis areas were rarely, if at all, surveyed.

During the 1990s, 1:100,000 USGS topographic maps were mostly used, because of the map features helped delineate vegetated areas on the ground aiding surveyors. Beginning in 2003 digital aerial sketch

mapping (DASM) systems were being tested and developed. The advantage of these systems was that the GPS system would track the aircraft on a digital display to aid the surveyor. However, poor GPS and electronic integration into the aircraft electronic systems necessitated the use of paper maps for back up during the early years of DASM utilization and overlap of technologies occurred.

During this time, substantial technological developments occurred to the transfer of data from paper maps to electronic format, as well. Previously, the 1990s survey data was transferred by hand from maps used in the airplane to a "master" map to document the damage, often using light tables. The advent of digitizing tables made converting the paper map data to a digital format easier. During the late 1990s and early 2000s this digital format was in the format of "extension" files, which had some limitations, and were distributed to users. Later, shape files (.shp and associated files) were used to compile and distribute the ADS data and forest provided maps to Forests and users. The data was also processed by Regional FHP GIS personnel and sent to FHTET to create a national dataset with a different set of standards. Beginning in 2015, the use of cloud technology and data collected on digital mobile sketch mapping (DMSM) systems were used to transfer data directly to a national data set. Currently, aerial surveyors upload and correct their data in the national cloud database from which the data is extracted to create regional ADS datasets.

More recent changes include the switch in 2016 from digital aerial sketch mapping (DASM) to digital mobile sketch mapping (DMSM). This change in software and technology coincided with an altered quantification methodology from "trees per acre" to "percent of trees affected" for polygons with insect and disease damage. This change assisted in incorporating data into the national ADS data set. Small areas are still recorded as points. A 5 level classification system is used to describe damage levels. Damage is recorded as a point, polygon, or grid cell feature and one causal agent is assigned to each feature. Depending upon feature type, the intensity of the damage is recorded differently. For point data, trees affected are classified into one of 5 levels that correspond to the number of trees killed associated with each point. For a polygon or grid cell data, the percentage of trees affected within each polygon or grid cell is classified into one of 5 levels for each polygon or grid cell associated with all trees within the polygon or grid cell data as estimated by the observer. This makes conclusions on intensity of impacts within a polygon difficult, because there is no baseline stand data that informs users of total trees/acre within a polygon (or trees/polygon). Thus, this report and products herein only use Region 4 ADS data from 1991-2015.

The collecting and transferring of ADS data is ever evolving and the collecting and processing of ADS data has rarely ever been consistent for more than two consecutive years. Combining and overlaying multiple years of ADS data has some nuances that evaluators need to be aware of when using ADS data.

Data Limitations

Factors that confound aerial detection surveys or affect surveyors and data quality include: air turbulence; cloud shadows; haze; smoke; timing; observer experience for an area; observer fatigue; temporary flight restrictions (TFRs) from fires and other factors; changing light angles throughout the day; and, biological windows of aerial signatures. Aerial detection survey data should never be used exclusively to make management recommendations. Ground verification of recorded disturbance is necessary, in order to verify causal agent and make biologically and ecologically appropriate recommendations and follow-up management decisions. Changes in coding of disturbances over time can make observing trends complex if not impossible for users who are not familiar with those coding variations. For example, subalpine fir mortality has been classified under five different damage causal agent codes due to the complexity of the interaction between abiotic and biotic factors. In addition, users cannot simply add up consecutive years of ADS data without skewing impacts, which may result in multiple counting of acres and over-estimating cumulative impact acres across years.

Insect and disease damage varies in visual tree signatures and host tree effects or symptoms. Familiarity with host types, biology and ecology of insects, and stand conditions (species present) affects data quality. As well, the quantity of data varies across survey area by number of years of flight data available (Figure 1 and Appendix A) as well as the flight method used during data collection (Region 4 Aerial Detection Survey History).

Regional Product Limitations

Within this report, the maps and tool output layers do not include vegetation data or stand-level conditions, this limits the context in which we may discuss impacts. Ecological diversity and stand characteristics play a critical role in insect and disease impacts across Region 4. We recognize the importance of fine tuning parameters to reflect appropriate insect biology, ecology, and host conditions or stand dynamics across such a diverse Region. For example, in two cases (Douglas-fir beetle and spruce beetle) we used trees per polygon estimates instead of trees per acre, in order to account for some of the limitations of the model when polygon size is large (Appendices B and E, Figures 2 and 5). Therefore, certain levels of damage, which may appear slight or are even listed as low severity on the maps, may in actuality represent complete loss of a particular host tree species in a mixed species stand. Making comparisons between diverse stand conditions is the largest limitation of the region-wide map products. Forest or District managers using the tool for their respective project areas should consider current stand conditions in their assessment area and collect the necessary stand-level vegetation data to decrease this constraint.

Multiple agent coding is not recognized by the tool, the tool only recognizes exclusive damage by agent. While this may not impact a regional scale impact estimation, it can represent a significant data limitation at the project level. Some damage areas may be missed due to this limitation. Additionally, disturbances, such as fire, floods, avalanche, and mechanical treatments, have occurred in some areas.

The defoliation model differs and offers a conservative estimate of western spruce budworm impact. Cumulative historic defoliation severity estimates are based on the ADS data attribute which indicates light, moderate, and heavy defoliation, respectively (Appendix G). The defoliation classes approximate crown dieback; however, host trees can re-foliate following budworm activity if buds remain viable. Consequently, there is reduced confidence in the defoliation estimation as ADS does not detect foliage re-flushing. Annual surveys may be timed such that the biological window of peak defoliation for a particular year is compromised to maximize ADS coverage across the Region. Low levels of defoliation in a given area or year reported by ground surveys are rarely captured by ADS. Moderate and high levels of defoliation have a higher probability of detection by ADS, under the best conditions for the ADS observer.

Data Strengths

The benefits of Region 4 ADS data include: ability to survey a large area; highly skilled surveyors with many years of experience and knowledge of the survey area; and a longstanding dataset with many years of data. Each summer the dataset grows, affording managers a bird's eye view of their respective districts, parks, forests and project areas. This observational data is best used as a course pointer for locating areas that have insect disturbance. This information is often utilized by Forest Health staff for assessing potential trends of insect-caused tree damage and mortality in an area. It is also used as a way to direct forest health staff and forest managers to areas of possible insect activity to quantify and confirm damage and causal agents through ground surveys. This is an especially valuable tool when managers note potential risk or impact to land management objectives.

Methods

Using ADS data, Forest Health Protection and Information Management developed products to offer more understanding and historical context of insect impacts in Region 4. Staffs utilized the Region 1 cumulative impact tool and protocol to build the Region 4 products. The cumulative impact tool offers an estimate of cumulative impacts (acres and/or trees) across this range of years (1991-2015) of ADS data. First, the tool creates GIS spatial layers of cumulative ADS impacts by looping through every year of data from all years included in a specified date range. The tool performs a Union function of first year and second year. That union output is run through the tool again with the next year's data. This happens until the range of years is exhausted. The tool then cumulatively unions each year's data to the first year. Each union procedure adds a TPA (trees per acre) field that sums TPA across the date range, adds an Acres field that reports acres for the unioned polygons, and adds a NoTrees (number of trees) field that provides the cumulative number of trees within polygons that were unioned over the date range (TPA * Acres).

Guidance and trouble shooting was a collaborative effort between Joel Egan, Region 1 Group leader/Entomologist, and Region 4 staff. Forest Health and Information Management met several times to edit, develop user guides, and fine tune products. This coincided with product reviews from pathologists and entomologists in Region 4. There are several instances where the Region 4 products vary from Region 1. These changes are described below.

The Region 4 effort included the entire survey area for Region 4 (this includes multiple land ownerships) in the analysis so that tool outputs are available for all surveyed lands. Due to differences in forest types and major forest insect events between Region 1 and Region 4, a different set of biotic agents were evaluated in Region 4. Region 4 efforts added several causal agents (spruce beetle, subalpine fir mortality complex, and western pine beetle) to the tool interface. The cumulative impact tool was applied to as many biotic agents as was practical. However, impacts from various agents are limited in space and time and therefore limited our capacity to accurately model cumulative impacts. Impacts from aspen dieback and mortality, pinyon engraver, balsam wooly adelgid (Figure 4), and defoliating diseases not included in this effort. The following six damage agents (see attached appendices), were included based on their historic and ecological influences:

Douglas-fir beetle (DFB),
Mountain pine beetle (MPB),
Subalpine fir mortality complex (SAFMC),
Spruce beetle (SB),
Western pine beetle (WPB), and
Western spruce budworm (WSBW).

In addition, the ADS data used by Region 4 covers a different range of years than what was used in Region 1. The years 1991 through 2015 were included in an attempt to offer historic estimations of major insect impacts across Region 4. The 1991 – 2015 datasets were collected with different quantification methodology (see Aerial detection Survey History section) than what is currently in use (DMSM, 2016-present).

The tool was modified to access Region 4 ADS data stored in the regional Spatial Database Engine (SDE) instance. The tool was adjusted to generate a file called Message.txt if any years were skipped. Skipped years are those where no records met the specified criteria for that year. Region 4 Information Management identified additional tool enhancements that were desired to improve output quality. However, it was discovered that attempts to edit the scripts were more involved than at first anticipated. For this reason, modifications to the tool were limited to those identified above to ensure

the integrity of the script and to minimize programming efforts, due to restricted time constraints. If funds and time become available, it is recommended that the identified improvements to the tool be performed.

It should be noted that an issue was identified in the original coding of the tool. A selection statement includes records with a DCA (Damage Code for Agent) value of 99999 for further processing. These records are areas with no damage surrounded by areas that have mapped with insect-caused damage and are an artifact from the historic versions of Esri ArcInfo coverage database format. The 99999 records should not be included and will inflate impacts. These areas were removed during post-processing of tool outputs by deleting records where the cumulative TPA field = 0. Any future runs of the tool should address this issue. Due to the difference in tool coding of the selection statement for the western spruce budworm (WSBW) causal agent, DCA values of 99999 are not an issue. It was also noted that the model only selects for exclusive damage by the agent. Areas where damage is caused by multiple agents are not included or may appear underestimated. This is important to note, especially for Region 4, since we have mixed conifer stands with host trees that are frequently impacted by several different biotic agents.

It is anticipated that geospatial outputs from this effort will be used in further analysis (down to Forest, District and possibly project area). It is important to understand the attributes of the data and how clipping or geoprocessing efforts affect data quality. Tables 1 and 2 are offered as a guide for clipping or additional geoprocessing of layers.

Table 1. The fields below include the tool outputs for Douglas-fir beetle, mountain pine beetle, spruce beetle, subalpine fir mortality complex, and western pine beetle. Field names and their descriptions are included to describe the geospatial outputs to end users. Comments include guidance on how additional geoprocessing does or does not impact values. In cases where clipping/geoprocessing DOES impact values, work arounds and guidance is offered to maintain data quality and tool integrity.

Field	Description	Comment
XXX_TPA1991_2015	Cumulative trees per acre within given spatial area – sums TPA field across years	Clipping or other geoprocessing does not impact this value
Acres_1991_2015	Acres for polygons unioned	Clipping or other geoprocessing **DOES** impact this value. Acres must be refreshed. Defined projection will impact results*.
NoTrees_1991_2015	Cumulative number of trees within polygons that were unioned over the year range	Clipping or other geoprocessing **DOES** impact this value. Number of trees must be refreshed by multiplying XXX_TPA1991_2015 * refreshed Acres_1991_2015
MPB_Severity	Qualitative severity class estimating impact based on cumulative trees/acre. 1 = low (>0 -<10 cumulative trees/acre); 2 = moderate (10-30); 3 = high (>30)	Clipping or other geoprocessing does not impact this value – based on MPB_TPA1991_2015

DFB_Severity SB_Severity	Qualitative severity class estimating impact based on cumulative trees per polygon (NoTrees_1991_2015). 1 = low (0 - < 500 trees per polygon); 2= moderate (>=500 - <= 1000 tree per polygon); 3 = high (>1000)	PLEASE NOTE that while clipping or other geoprocessing **DOES** impact this value, the original severity should be retained to reflect conditions of the polygon in the context of surrounding lands.

Table 2. The fields below include the tool outputs for western spruce budworm. Field names and their descriptions are included to describe the geospatial outputs to end users. Comments include guidance on how additional geoprocessing does or does not impact values. In cases where clipping/geoprocessing DOES impact values, work arounds and guidance is offered to maintain data quality and tool integrity.

Field	Description	Comment
SBW_1991_2015	Cumulative defoliation severity based on ADS survey data attribute (SEVERITY1, SEVERITY2, SEVERITY3) which indicates light, moderate, and heavy defoliation.	Clipping or other geoprocessing does not impact this value
WSBW_IND_DRSCRIP	Qualitative description estimating impact 1 = low (> 0 - < 1); 2 = moderate (>= 1 and < 3); 3 = high (>= 3) based on cumulative defoliation severity.	Clipping or other geoprocessing does not impact this value – based on SBW_1991_2015
ACRES_1991_2015	Acres for polygons unioned.	Clipping or other geoprocessing **DOES** impact this value. Acres must be refreshed. Defined projection will impact results*.
S_ACRES_1991_2015	Weighted acres using most severe defoliation category as baseline (acres from high * 1.0, acres from moderate * 0.5, acres from low * 0.1). This weighted acreage represents a conservative estimate of WSBW observed impacts in terms of level of crown defoliation and likely growth/vigor reductions as represented by low, moderate, and high classes.	Clipping or other geoprocessing **DOES** impact this value. Acres must be refreshed utilizing appropriate multiplier. Defined projection will impact results*.

Results and Products

Resulting maps (Figures 1-7) and Tables 3 and 4 include estimations of historic impacts across Region 4. Table 3 includes all land ownerships that were surveyed. Table 4 includes estimations for National Forest System lands. Visual impacts are subdued, due to the regional scale of maps presented in this report. The scale at which ADS data is collected is often down to the tree level. Viewing the layers in ArcMap or as a story map allows users to scroll and zoom in to forests, districts, and project area boundaries within Region 4 including non-Forest Service managed lands for a detailed assessment. This allows a better sense of insect impact estimations at a finer scale. The layer files bring the data in symbolized as depicted on the maps in this report. As well .pdf maps (Figures 1-7) are available digitally or by email.

We list best available values of acres and trees impacted by agent to further explain the data and tool outputs depicted in the maps (Table 3). Estimations of acres impacted by western spruce budworm and mountain pine beetle highlight Region 4's most noticeable forest health events, in recent history. Based on ADS data, the tool estimates nearly 53 million trees impacted by mountain pine beetle alone, accounting for nearly 82% of the total trees impacted. While the cumulative impact tool estimates that spruce beetle has impacted more than 721,000 acres, this also accounts for over 4 million trees killed by spruce beetle. Region 4 National Forest System (NFS) lands alone include 34 million acres. According to ADS data and the cumulative impact tool outputs (Table 4), approximately one-third of NFS lands have been impacted by insect and disease from 1991 to 2015.

Final data is located in the regional SDE instance and can be accessed using layer files located here: T:\FS\Reference\GIS\r04\LayerFile\R04.

Table 3. Estimations of cumulative acres and trees impacted, between 1991 and 2015, by causal agent are listed to show the numerical outputs of the tool (Egan 2018) used in the products for Region 4. Numbers are rounded to nearest thousand. These values are the result of summing the acres field for estimated cumulative acres impacted[1]. Based on how ADS data is collected and how the tool operates, we are only able to list acres and/or trees for particular agents[2].

Insect Agent	Estimated cumulative acres impacted (1991-2015)[1]	Estimated cumulative trees impacted (1991-2015)[2]	Host tree(s) impacted
Douglas-fir beetle	1,188,000	2,626,000	Douglas-fir
Mountain pine beetle	4,799,000	52,805,000	Limber pine, lodgepole pine, ponderosa pine, whitebark pine
Subalpine fir mortality complex	1,693,000	4,545,000	Subalpine fir
Spruce beetle	721,000	4,243,000	Engelmann spruce, blue spruce
Western pine beetle	133,000	169,000	Ponderosa pine
Western spruce budworm	3,452,000	N/A[2]	Douglas-fir, subalpine fir, white fir, grand fir
Total	11,986,000	64,388,000[2]	

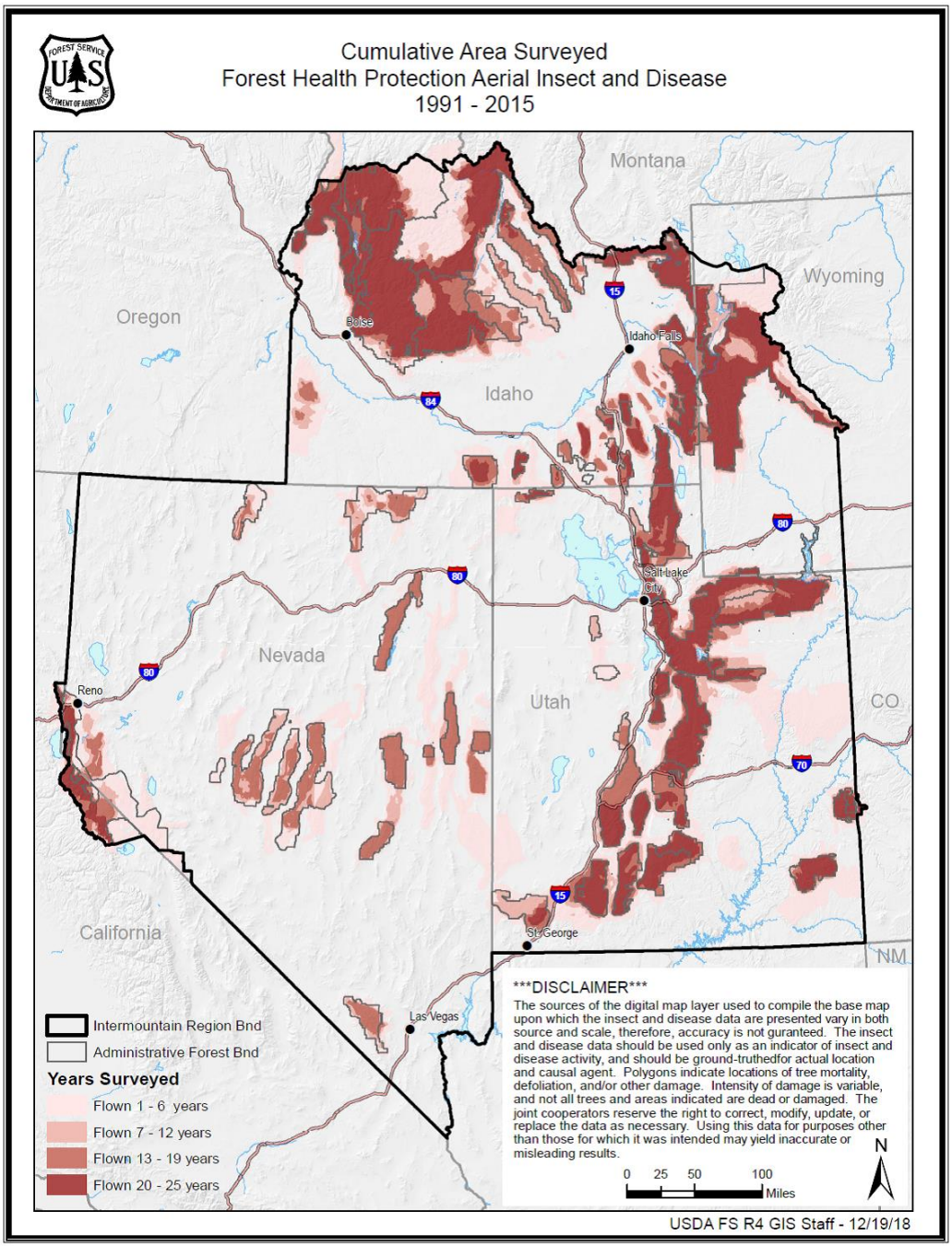
Table 4. Estimations of cumulative acres and trees impacted on Region 4 National Forest System (NFS) lands, between 1991 and 2015, are listed by causal agent to illustrate the numerical outputs of the cumulative impact tool (Egan 2018). Land ownership was burned into the cumulative impact tool outputs to derive the following estimations. Numbers are rounded to nearest thousand. *Western pine beetle numbers are considerably smaller. This required different rounding methods. In order to offer a more accurate cumulative impact estimate, where there are < 50 trees recorded for western pine beetle (Bridger-Teton NF and Caribou-Targhee NF) we have not included those values. These values are the result of summing the acres field for estimated cumulative acres impacted[1]. These values are the result of summing the trees field for estimated cumulative trees impacted[2]. Based on how ADS data is collected and how the tool operates, we are only able to list acres and/or trees for particular agents[2].

Biotic Agent Forest	**Estimated Cumulative Acres Impacted (1991-2015)[1]**	**Estimated Cumulative Trees Impacted (1991-2015)[2]**
Douglas-fir beetle		
Ashley	68,000	198,000
Boise	181,000	313,000
Bridger-Teton	101,000	251,000
Caribou-Targhee	16,000	246,000
Dixie	27,000	61,000
Fishlake	27,000	59,000
Humboldt-Toiyabe	50	100
Manti La-Sal	37,000	89,000
Payette	149,000	243,000
Salmon-Challis	159,000	346,000
Sawtooth	135,000	319,000
Uinta-Wasatch-Cache	164,000	127,000
NFS Total	1,064,050	2,252,100
Mountain pine beetle		
Ashley	281,000	2,567,000
Boise	140,000	790,000
Bridger-Teton	975,000	6,424,000
Caribou-Targhee	309,000	3,327,000
Dixie	48,000	64,000
Fishlake	11,000	19,000
Humboldt-Toiyabe	89,000	157,000
Manti La-Sal	19,000	31,000
Payette	325,000	3,120,000
Salmon-Challis	1,376,000	2,314,000
Sawtooth	373,000	3,776,000
Uinta-Wasatch-Cache	391,000	5,087,000
NFS Total	4,337,000	27,676,000

Spruce beetle		
Ashley	64,000	378,000
Boise	3,000	5,000
Bridger-Teton	64,000	795,000
Caribou-Targhee	3,000	10,000
Dixie	88,000	362,000
Fishlake	24,000	218,000
Humboldt-Toiyabe	100	200
Manti La-Sal	113,000	658,000
Payette	122,000	172,000
Salmon-Challis	700	1,000
Sawtooth	1,000	1,000
Uinta-Wasatch-Cache	139,000	987,000
NFS Total	621,800	3,587,200
Subalpine fir mortality complex		
Ashley	26,000	83,000
Boise	40,000	46,000
Bridger-Teton	474,000	996,000
Caribou-Targhee	188,000	383,000
Dixie	90,000	378,000
Fishlake	118,000	443,000
Humboldt-Toiyabe	34,000	141,000
Manti La-Sal	110,000	244,000
Payette	12,000	27,000
Salmon-Challis	72,000	240,000
Sawtooth	319,000	121,000
Uinta-Wasatch-Cache	183,000	600,000
NFS Total	1,666,000	3,702,000
Western pine beetle		
Ashley	1,000	1,500
Boise	64,000	60,000
Bridger-Teton	*	*
Caribou-Targhee	*	*
Dixie	2,000	4,000
Fishlake	300	400
Humboldt-Toiyabe	1,000	1,000
Manti La-Sal	2,000	2,000
Payette	26,000	44,000
Salmon-Challis	5,000	7,000
Sawtooth	800	800
Uinta-Wasatch-Cache	1,500	50
NFS Total	103,600	120,750

Western spruce budworm		
Ashley	4,000	N/A[2]
Boise	790,000	"
Bridger-Teton	80,000	"
Caribou-Targhee	579,000	"
Dixie	138,000	"
Fishlake	181,000	"
Humboldt-Toiyabe	500	"
Manti La-Sal	14,000	"
Payette	342,000	"
Salmon-Challis	636,000	"
Sawtooth	259,000	"
Uinta-Wasatch-Cache	8,000	"
NFS Total	3,031,500	N/A[2]

The Cumulative Area Surveyed displays intensity or quantity of ADS data for specific locations across Region 4. The map displays coverage of ADS flights between 1991 and 2015 (Figure 1). This map is intended to assist product users in determining locations that have more or less data and can inform managers on the general confidence of mapped data based on quantity of data. Inherent differences will exist for those areas that have larger or smaller datasets. For example, in southern portions of Nevada and Utah special ADS surveys were conducted in 2003 and 2004 to document the widespread pinyon mortality. Typically, these areas are not surveyed due to them not being in the timber base for the region. Similarly wilderness areas, like the Frank Church River of No Return Wilderness, and some other mountain ranges are surveyed sporadically. See Appendix A for additional information.


Cumulative Area Surveyed
Forest Health Protection Aerial Insect and Disease
1991 - 2015
Montana
Wyoming
Oregon
Idaho
Nevada
Utah
CO
NM
California
Boise
Idaho Falls
Salt Lake City
Reno
St. George
Las Vegas
Intermountain Region Bnd
Administrative Forest Bnd
Years Surveyed
Flown 1 - 6 years
Flown 7 - 12 years
Flown 13 - 19 years
Flown 20 - 25 years
DISCLAIMER
The sources of the digital map layer used to compile the base map upon which the insect and disease data are presented vary in both source and scale, therefore, accuracy is not guranteed. The insect and disease data should be used only as an indicator of insect and disease activity, and should be ground-truthedfor actual location and causal agent. Polygons indicate locations of tree mortality, defoliation, and/or other damage. Intensity of damage is variable, and not all trees and areas indicated are dead or damaged. The joint cooperators reserve the right to correct, modify, update, or replace the data as necessary. Using this data for purposes other than those for which it was intended may yield inaccurate or misleading results.
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USDA FS R4 GIS Staff - 12/19/18

Figure 1. The map displays coverage of ADS flights between 1991 and 2015. The map shows yearly ADS data by quartiles. For instance, areas with >0-25% coverage have >0-6 years of data; 26-49% coverage have 7-12 years of data; 50-74% coverage have 13-19 years of data and >75% coverage have 20-25 years of data.

The following map (Figure 2) includes cumulative historic impacts by Douglas-fir beetle spanning 1991-2015. Trees per polygon estimations were used to categorize severity of impacts as low, moderate and high. The trees per polygon estimation accounts for insect impacts that tend to be mapped as large polygons across the landscape. See Appendix B for additional information.

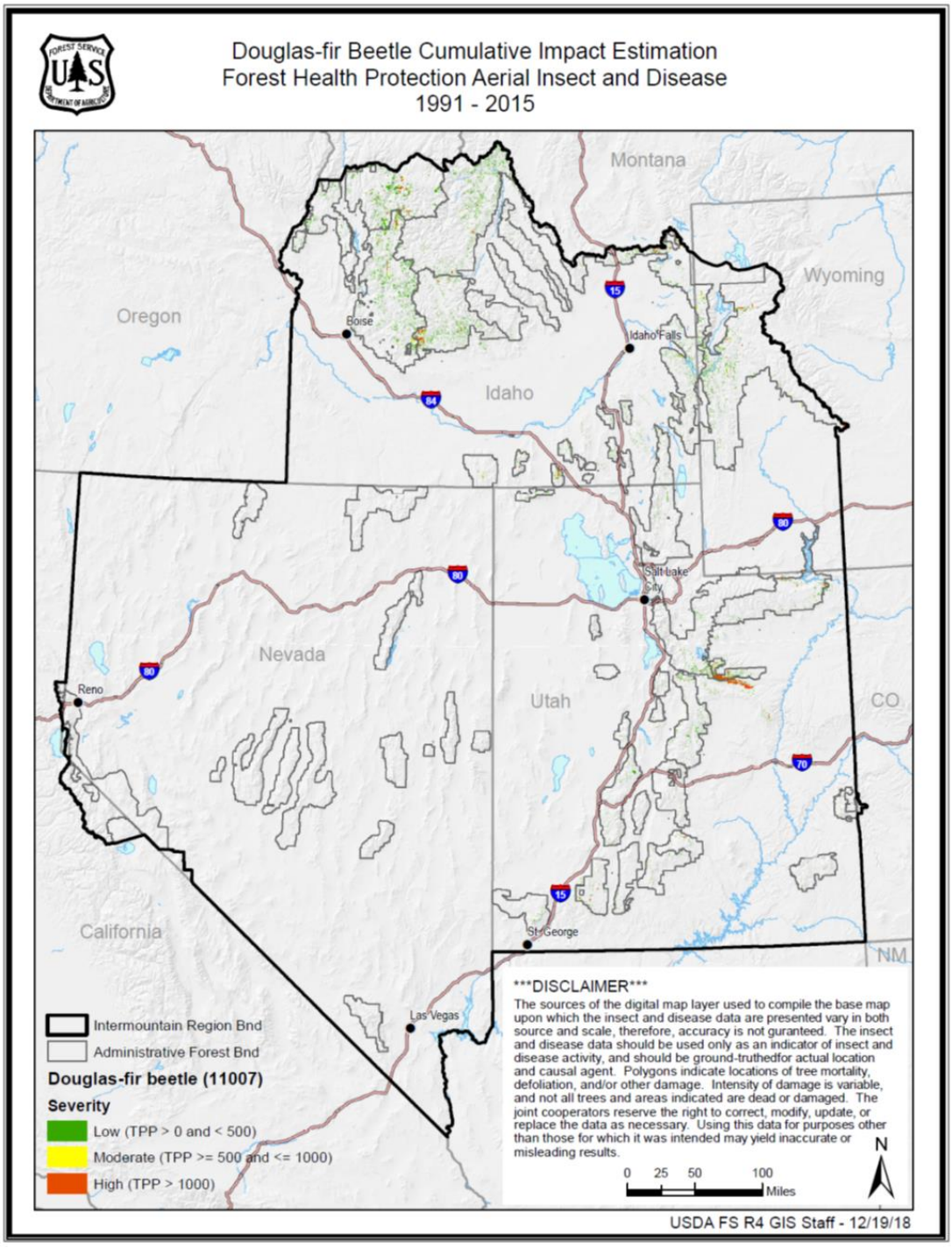
Douglas-fir Beetle Cumulative Impact Estimation
Forest Health Protection Aerial Insect and Disease
1991 - 2015
Montana
Wyoming
Oregon
Idaho
Boise
Idaho Falls
Salt Lake City
Nevada
Utah
CO
NM
Reno
California
St George
Las Vegas
Intermountain Region Bnd
Administrative Forest Bnd
Douglas-fir beetle (11007)
Severity
Low (TPP > 0 and < 500)
Moderate (TPP >= 500 and <= 1000)
High (TPP > 1000)
DISCLAIMER
The sources of the digital map layer used to compile the base map upon which the insect and disease data are presented vary in both source and scale, therefore, accuracy is not guranteed. The insect and disease data should be used only as an indicator of insect and disease activity, and should be ground-truthedfor actual location and causal agent. Polygons indicate locations of tree mortality, defoliation, and/or other damage. Intensity of damage is variable, and not all trees and areas indicated are dead or damaged. The joint cooperators reserve the right to correct, modify, update, or replace the data as necessary. Using this data for purposes other than those for which it was intended may yield inaccurate or misleading results.
0 25 50 100
Miles
N
USDA FS R4 GIS Staff - 12/19/18

Figure 2. The estimation of cumulative historical impacts of Douglas-fir beetle spanning 1991 - 2015. The map displays low, moderate and high severity categories based on estimates of cumulative insect-killed trees per polygon. For instance, polygons with 0-499 Douglas-fir beetle-killed trees are indicated as low impact; 500-1000 trees per polygon are moderate; >1000 trees per polygon indicate high impacts.

The mountain pine beetle map includes estimates of cumulative historic impacts by mountain pine beetle spanning 1991-2015 for all the hosts of mountain pine beetle (Figure 3). Those hosts within this dataset include: lodgepole pine, whitebark pine, limber pine, and ponderosa pine. The estimations of cumulative tree mortality were developed using ADS data (insect-killed trees per acre) and the Region 4 amendments made to Cumulative Mortality Tool outputs. Please note that areas in central and southern Utah have considerably less host type or contiguous stands of ponderosa pine. For ponderosa pine tree mortality in southern Utah, additional data should be analyzed because multiple bark beetle species overlap in distribution. Often, we find a complex of bark beetles (round headed, western, and mountain pine beetle) attacking pine hosts in this portion of the region. Impacts appear underestimated, due to the number of insect agents and lower density of hosts in central and southern Utah and Nevada. See Appendix C for additional information.

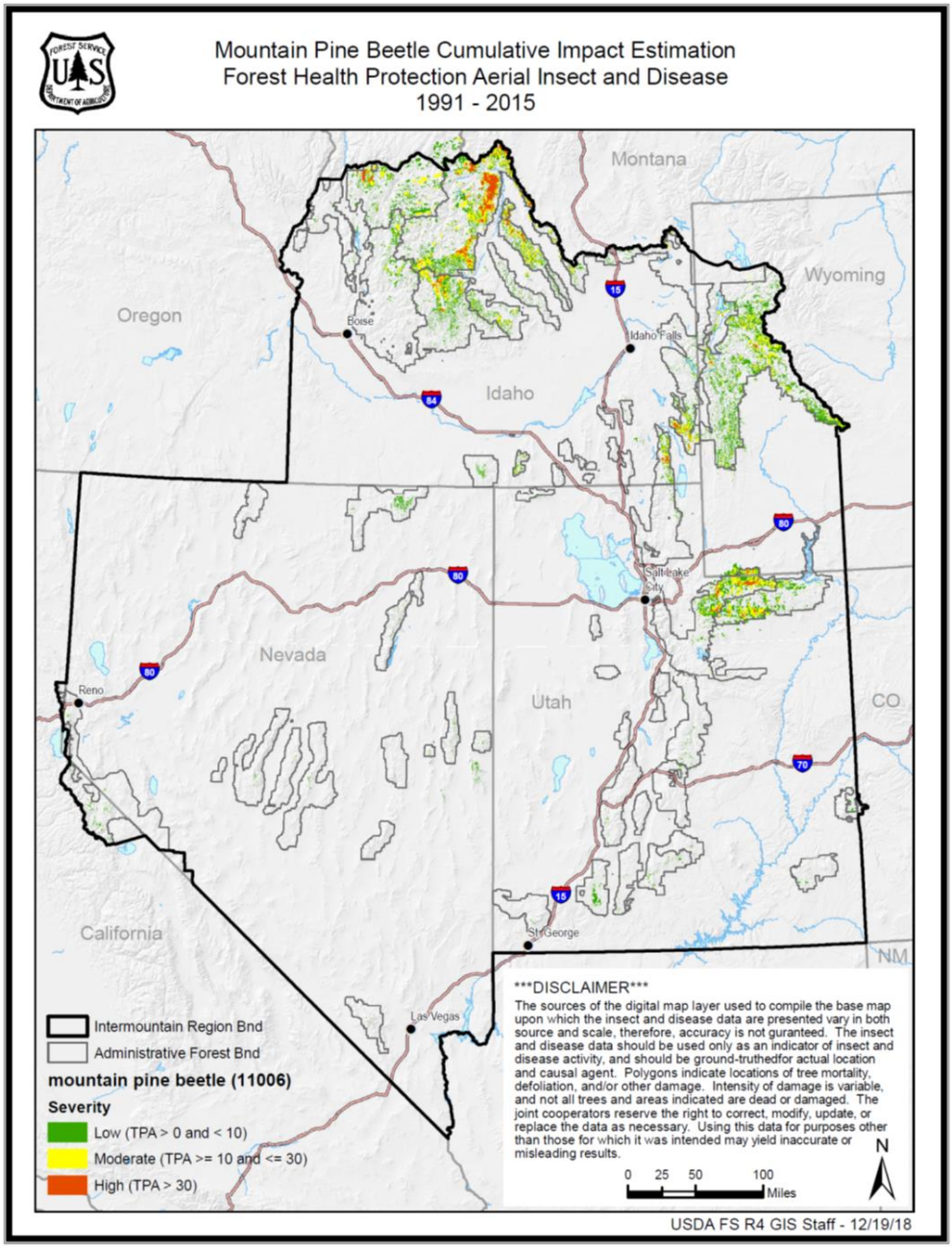
Mountain Pine Beetle Cumulative Impact Estimation
Forest Health Protection Aerial Insect and Disease
1991 - 2015
Montana
Wyoming
Oregon
Idaho
Boise
Idaho Falls
Salt Lake City
Nevada
Reno
Utah
CO
NM
California
St George
Las Vegas
Intermountain Region Bnd
Administrative Forest Bnd
mountain pine beetle (11006)
Severity
Low (TPA > 0 and < 10)
Moderate (TPA >= 10 and <= 30)
High (TPA > 30)
DISCLAIMER
The sources of the digital map layer used to compile the base map upon which the insect and disease data are presented vary in both source and scale, therefore, accuracy is not guranteed. The insect and disease data should be used only as an indicator of insect and disease activity, and should be ground-truthedfor actual location and causal agent. Polygons indicate locations of tree mortality, defoliation, and/or other damage. Intensity of damage is variable, and not all trees and areas indicated are dead or damaged. The joint cooperators reserve the right to correct, modify, update, or replace the data as necessary. Using this data for purposes other than those for which it was intended may yield inaccurate or misleading results.
0 25 50 100
Miles
N
USDA FS R4 GIS Staff - 12/19/18

Figure 3. The estimation of cumulative historical impacts of mountain pine beetle spanning 1991 - 2015. The map displays low, moderate and high severity categories based on insect-killed trees per acre. For instance, low severity estimations represent those with >0-10 trees per acre; <10-30 trees per acre is moderate severity; >30 trees per acre indicates high severity.

The following map (Figure 4) displays the footprint of estimated cumulative historic impacts by subalpine fir (SAF) mortality complex spanning 1991-2015. The estimations of cumulative tree mortality were developed using ADS data and the Region 4 amendments made to R1 Cumulative Mortality Tool. In Region 4, this complex is an assortment of bark beetle species often involving a few to several of the following bark beetles in an individual tree: *Crypturgus borealis*, *Dyocetes confusus*, *Gnathotrichus suleatus*, *Pissodes burkei*, *Pissodes similis*, *Pityokteines minutus*, *Pityokteines lasiocarpi*, *Pityophthorus pseudotsugae*, *Pityophthorus opaculus*, *Scolytus opaculus*, *Scolytus ventralis*, and *Trypodendron lineatum*. Their attacks are often initiated by additional stressors such as drought and an assortment of tree diseases. Within the timeframe of this model, the invasive balsam wooly adelgid was confirmed in Idaho and later in Utah, we suspect that some of this footprint includes impacts from balsam woolly adelgid as surveyors were adjusting their eye to the subtle difference between balsam woolly adelgid damage and tree mortality caused by this complex of agent in subalpine fir. See Appendix D for additional information.

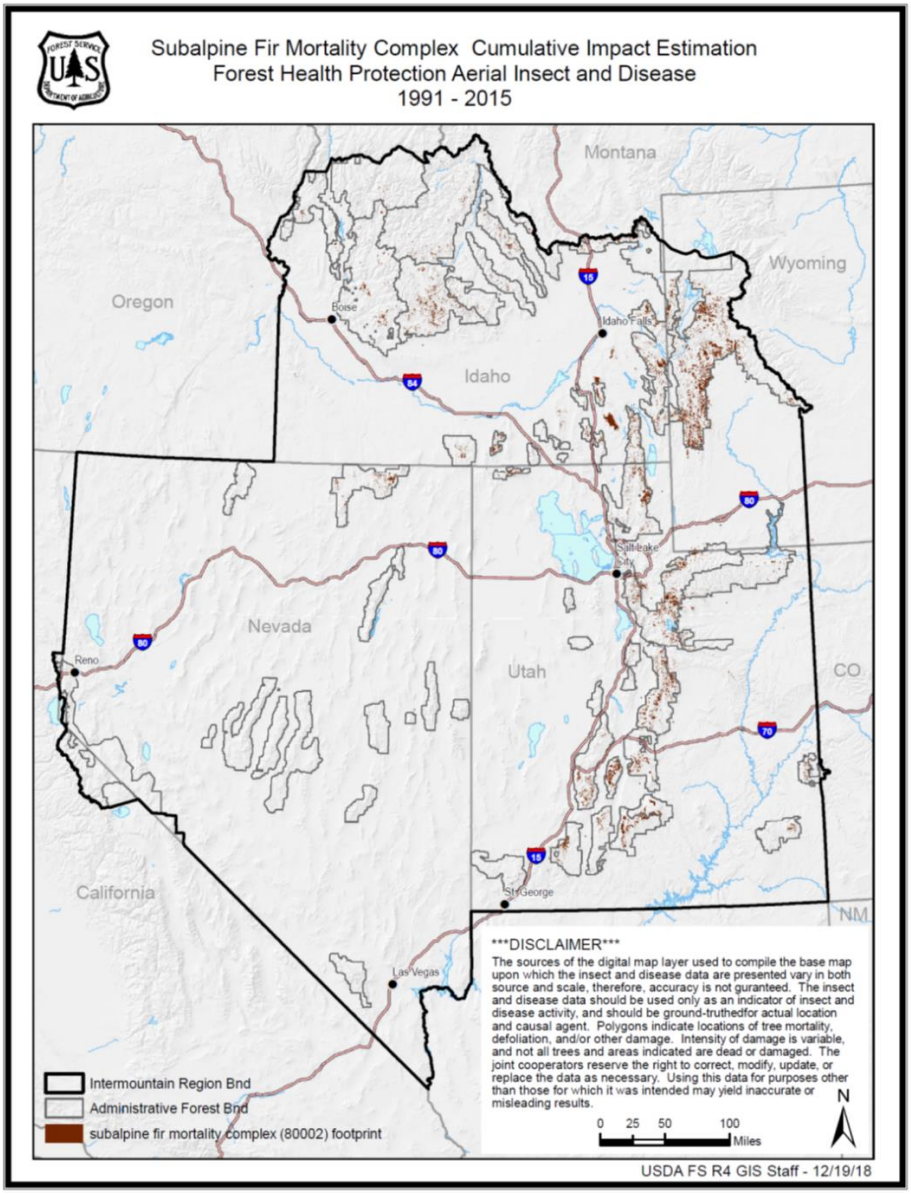
Subalpine Fir Mortality Complex Cumulative Impact Estimation
Forest Health Protection Aerial Insect and Disease
1991 - 2015
Montana
Wyoming
Oregon
Idaho
Boise
Idaho Falls
Nevada
Utah
CO
NM
California
Reno
Las Vegas
St George
Salt Lake City
DISCLAIMER
The sources of the digital map layer used to compile the base map upon which the insect and disease data are presented vary in both source and scale, therefore, accuracy is not guranteed. The insect and disease data should be used only as an indicator of insect and disease activity, and should be ground-truthedfor actual location and causal agent. Polygons indicate locations of tree mortality, defoliation, and/or other damage. Intensity of damage is variable, and not all trees and areas indicated are dead or damaged. The joint cooperators reserve the right to correct, modify, update, or replace the data as necessary. Using this data for purposes other than those for which it was intended may yield inaccurate or misleading results.
Intermountain Region Bnd
Administrative Forest Bnd
subalpine fir mortality complex (80002) footprint
0 25 50 100
Miles
N
USDA FS R4 GIS Staff - 12/19/18

Figure 4. The estimation of cumulative historical impacts of subalpine fir mortality complex spanning 1991 - 2015. The map displays the total footprint of mapped impacts from the insects and diseases commonly associated with subalpine fir mortality in Region 4.

The following map (Figure 5) includes cumulative historic impacts by spruce beetle spanning 1991-2015. Trees per polygon estimations were used to categorize severity of impacts as low, moderate and high. The trees per polygon estimation accounts for insect impacts that tend to be mapped as large polygons across the landscape, as is often seen with spruce beetle. Fortunately, the tail end of the spruce beetle outbreak on the Payette National Forest was captured by this map. Most of that mortality occurred in the late 1980s and 1990, just prior to the timeframe of this Cumulative Mortality map. See Appendix E for additional information.

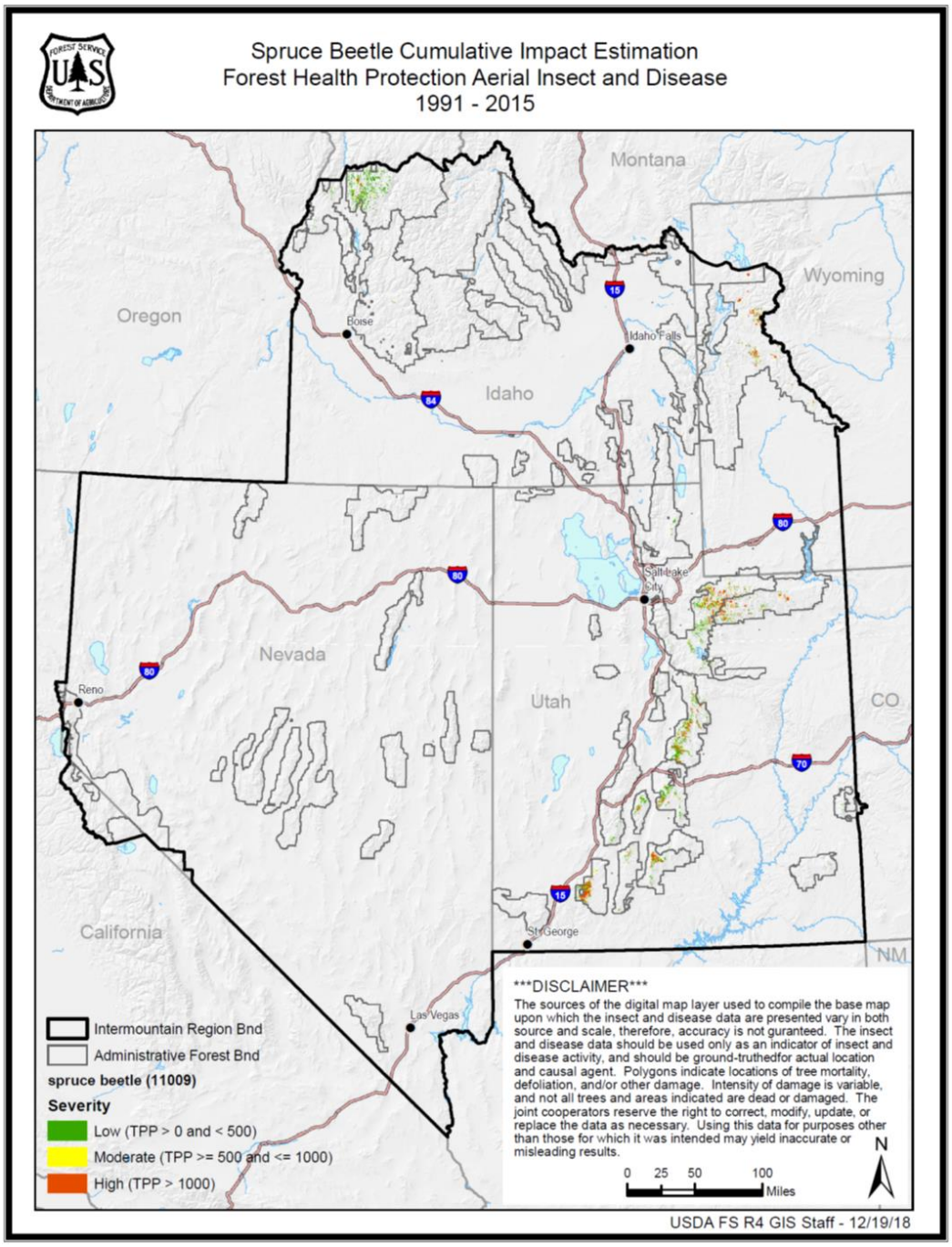
Spruce Beetle Cumulative Impact Estimation
Forest Health Protection Aerial Insect and Disease
1991 - 2015
Montana
Wyoming
Oregon
Idaho
Boise
Idaho Falls
Salt Lake City
Nevada
Reno
Utah
CO
NM
California
St George
Las Vegas
Intermountain Region Bnd
Administrative Forest Bnd
spruce beetle (11009)
Severity
Low (TPP > 0 and < 500)
Moderate (TPP >= 500 and <= 1000)
High (TPP > 1000)
DISCLAIMER
The sources of the digital map layer used to compile the base map upon which the insect and disease data are presented vary in both source and scale, therefore, accuracy is not guranteed. The insect and disease data should be used only as an indicator of insect and disease activity, and should be ground-truthedfor actual location and causal agent. Polygons indicate locations of tree mortality, defoliation, and/or other damage. Intensity of damage is variable, and not all trees and areas indicated are dead or damaged. The joint cooperators reserve the right to correct, modify, update, or replace the data as necessary. Using this data for purposes other than those for which it was intended may yield inaccurate or misleading results.
0 25 50 100
Miles
N
USDA FS R4 GIS Staff - 12/19/18

Figure 5. The estimation of cumulative historical impacts of spruce beetle spanning 1991 - 2015. The map displays low, moderate and high severity categories based on insect-killed trees per polygon. For instance, polygons with >0-499 spruce beetle-killed trees are indicated as low impact; 500-1000 trees per polygon are moderate; >1000 trees per polygon indicate high severity.

The following map (Figure 6) includes cumulative historic impacts by western pine beetle spanning 1991-2015. The estimations of cumulative tree mortality were developed using ADS data and the Region 4 amendments made to R1 Cumulative Mortality Tool. Please note that areas in central and southern Utah have considerably less host type. Often, we find a complex of bark beetles attacking ponderosa pine hosts in this portion of the region. Considering only impacts by western pine beetle will underestimate total impacts to ponderosa pine by bark beetles due to the number of bark beetles and lower density of hosts. See Appendix F for additional information.

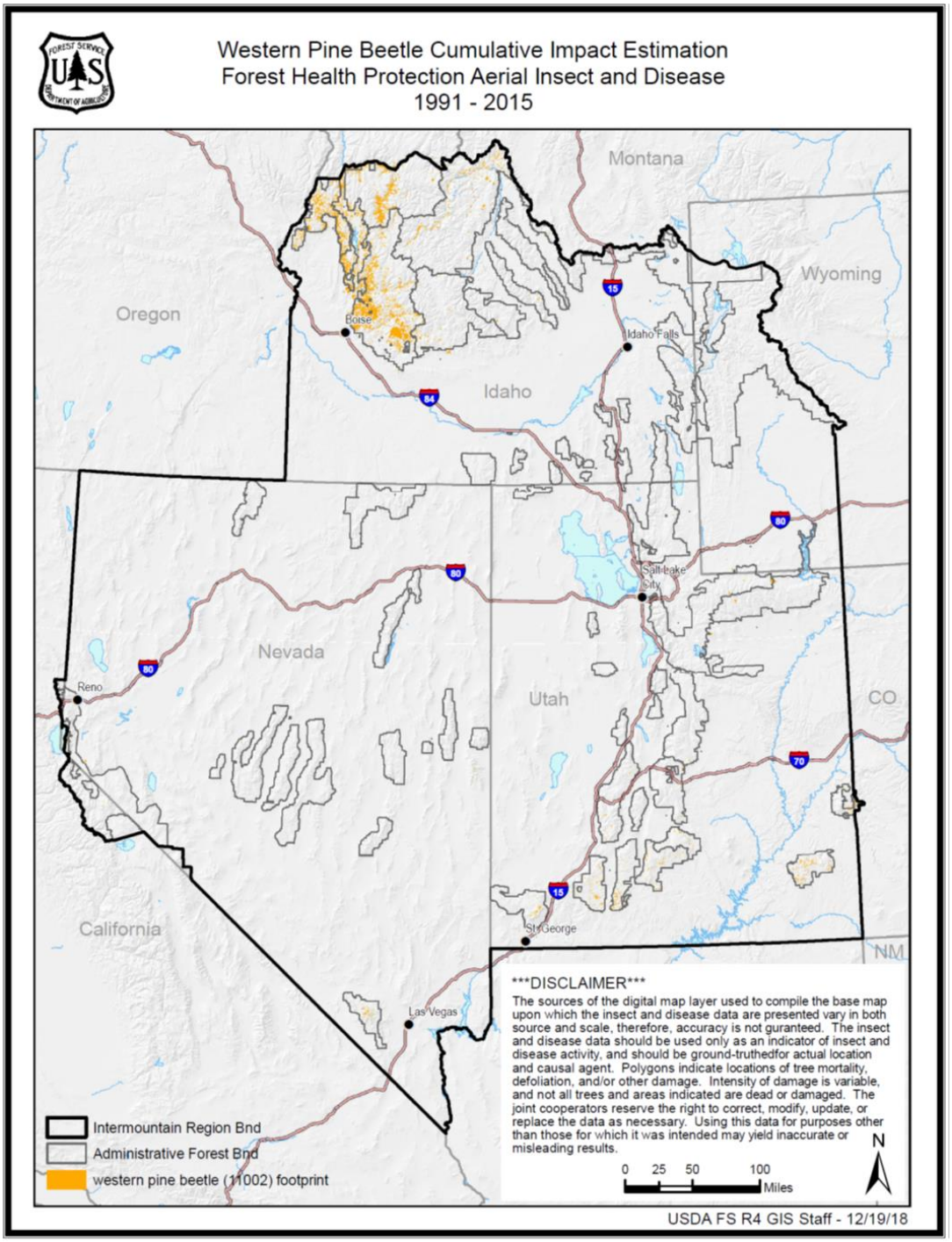
Western Pine Beetle Cumulative Impact Estimation
Forest Health Protection Aerial Insect and Disease
1991 - 2015
Montana
Wyoming
Oregon
Idaho
Boise
Idaho Falls
Salt Lake City
Nevada
Reno
Utah
CO
NM
California
St George
Las Vegas
DISCLAIMER
The sources of the digital map layer used to compile the base map upon which the insect and disease data are presented vary in both source and scale, therefore, accuracy is not guranteed. The insect and disease data should be used only as an indicator of insect and disease activity, and should be ground-truthedfor actual location and causal agent. Polygons indicate locations of tree mortality, defoliation, and/or other damage. Intensity of damage is variable, and not all trees and areas indicated are dead or damaged. The joint cooperators reserve the right to correct, modify, update, or replace the data as necessary. Using this data for purposes other than those for which it was intended may yield inaccurate or misleading results.
N
0 25 50 100
Miles
Intermountain Region Bnd
Administrative Forest Bnd
western pine beetle (11002) footprint
USDA FS R4 GIS Staff - 12/19/18

Figure 6. The estimation of cumulative historical impacts of western pine beetle spanning 1991 - 2015. The map displays the total footprint of mapped impacts (trees per acre) from the western pine beetle in Region 4.

This map (Figure 7) includes estimates of cumulative historic impacts from western spruce budworm spanning 1991-2015 in Region 4. Timing of surveys and environmental factors (smoke and clouds) affect lighting of landscape and aerial signature of western spruce beetle damage. Although the overstory is most observable from the aircraft, areas with consecutive high levels of defoliation may have impacts to understory or intermediate size hosts. Top-kill and branch dieback is also possible in areas with areas of consecutive high defoliation levels. See Appendix G for additional information.

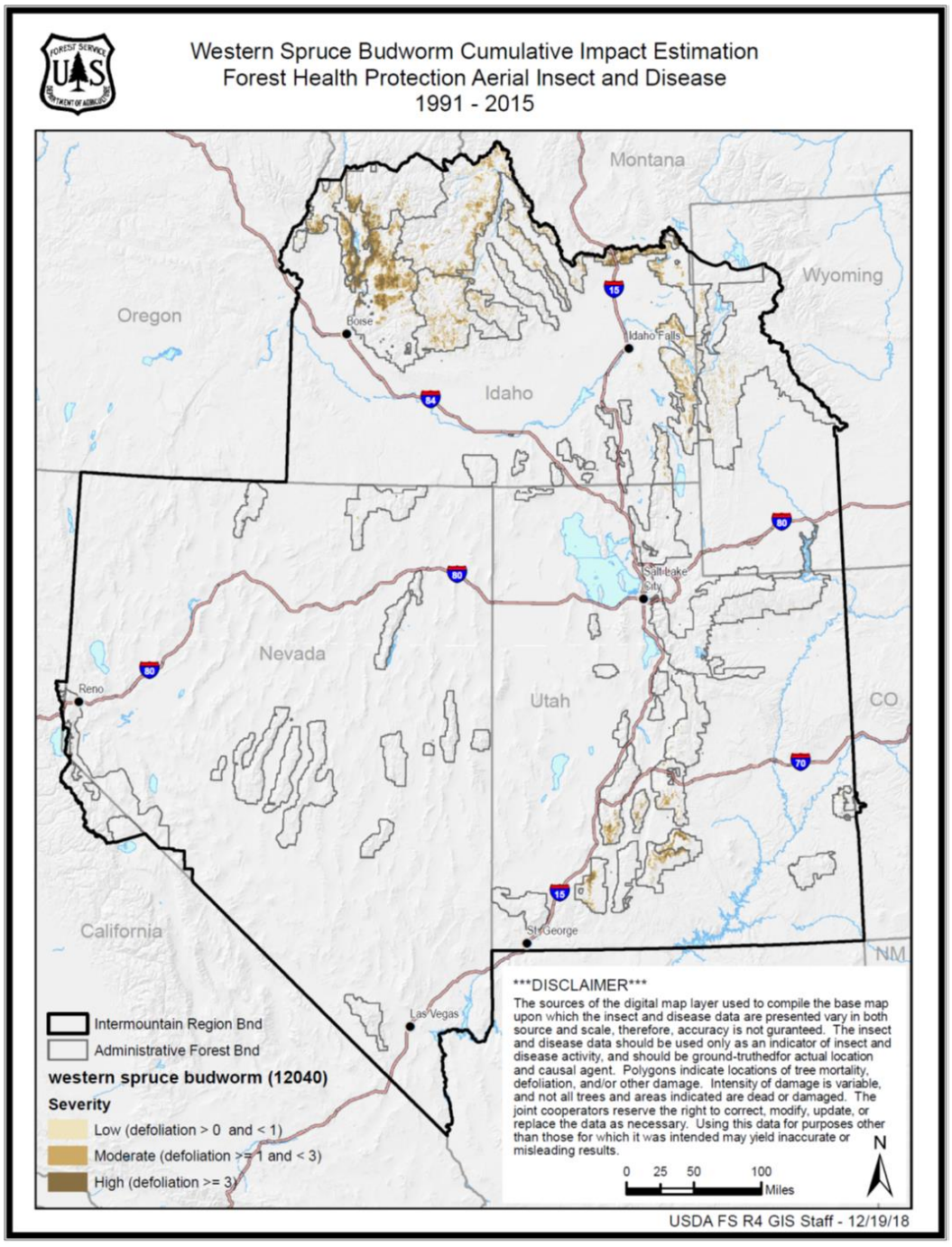
Western Spruce Budworm Cumulative Impact Estimation
Forest Health Protection Aerial Insect and Disease
1991 - 2015
Montana
Wyoming
Oregon
Boise
Idaho Falls
Idaho
Salt Lake City
Nevada
Reno
Utah
CO
California
St George
NM
Las Vegas
Intermountain Region Bnd
Administrative Forest Bnd
western spruce budworm (12040)
Severity
Low (defoliation > 0 and < 1)
Moderate (defoliation >= 1 and < 3)
High (defoliation >= 3)
DISCLAIMER
The sources of the digital map layer used to compile the base map upon which the insect and disease data are presented vary in both source and scale, therefore, accuracy is not guranteed. The insect and disease data should be used only as an indicator of insect and disease activity, and should be ground-truthedfor actual location and causal agent. Polygons indicate locations of tree mortality, defoliation, and/or other damage. Intensity of damage is variable, and not all trees and areas indicated are dead or damaged. The joint cooperators reserve the right to correct, modify, update, or replace the data as necessary. Using this data for purposes other than those for which it was intended may yield inaccurate or misleading results.
0 25 50 100
Miles
N
USDA FS R4 GIS Staff - 12/19/18

Figure 7. Weighted acres using the most severe defoliation category is baseline (acres from high * 1.0, acres from moderate * 0.5, acres from low * 0.1). This weighted acreage represents a conservative estimate of western spruce budworm overstory impacts or levels of crown defoliation and growth/vigor reductions as represented by low, moderate, and high classes.

Conclusion

The cumulative impact tool offers estimations of historic insect impacts. These estimations are useful for informing managers on project area location and project focus. For example, model outputs may assist managers in: forest plan revision and assessments, prioritizing vegetation treatments, fire behavior estimations and fire personnel safety, access, as well as meeting developed recreation objectives. As a reminder to users, ADS data is best used with an understanding of methodology of data capture and processing, as well as data limitations and strengths, and potential impacts of each of the insect disturbances and their ecology. Recent changes in ADS quantification methodology and a lack of crossover estimations between current data and data prior to 2016 has affected our ability to show trends beyond 2015 in this report. In the meantime, we offer the cumulative impact tool and map products for estimating past impacts (1991-2015). Tool outputs for all agents remain useful in illustrating where impacts have occurred. These products represent an incentive to begin developing additional tools and products that are practical for the current needs of our partners.

In the beginning, there was intent to align products with those created by Region 1, several ecological discrepancies between Region 4 and 1 required us to make the amendments we have discussed in the report. Trees per polygon was the suggested work around that we utilized to account for insect-caused damage that created large polygons between 1991 and 2015 (Douglas-fir beetle and spruce beetle). Geoprocessing or clipping of tool outputs / layers for Douglas-fir beetle and spruce beetle layers will impact severity ranking of polygons that are clipped. Maintaining the previous polygon severity ranking is important for consistency and data quality in future products rendered from these layers.

Future goals should focus on amending this tool for previously discussed coding issues, and including updates to maintain quality outputs for Douglas-fir tussock moth, balsam wooly adelgid, and aspen dieback and decline. Most, if not all of the agents recorded by ADS, are good candidates for estimating impact using the trees per polygon method. However, time constraints and the current demand for cumulative impact estimations did not allow for additional runs of the tool. A final story map is in development and will available momentarily through Arc GIS online. The ecological impacts of these and other biotic agents will continue to cause dramatic effects in Region 4 often confounding ongoing management objectives. Finding ways to incorporate and cross walk vegetation data at the stand or watershed level into current and historic ADS map products can provide additional insights to potential vegetation impacts of the agents mapped by ADS and can help develop predictions for future outbreaks.

Forest health protection staff mission is to protect and improve the health of America's forests. One of the elements to accomplish this mission is to develop tools and new technologies that meet current management needs. This effort could not have been completed without Region 4 Information Management staff assisting with GIS support and processing of geospatial data. Please contact Forest Health Protection (Ogden Field Office, Danielle Malesky, Entomologist, dmalesky@fs.fed.us, 801-476-9720 ext. 220; Boise Field Office, Carl Jorgensen, Entomologist, cljorgensen@fs.fed.us, 208-373-4225) or Information Management (Teresa Rhoades, GIS Program Manager, trhoades@fs.fed.us, 801 625-5273) with questions regarding the products and their appropriate use.

Acknowledgements

We thank Joel Egan in Region 1, Missoula Field Office for taking countless phone calls and skype messages, offering thoughtful guidance and assistance, and troubleshooting with us along the way. We thank Terri Johnson, who was critical in the initial trials of the cumulative impact tool using Region 4 data. We thank Region 4 Forest Health staffs for their thorough reviews and thoughtful dialogue. Last but not least, we thank leadership for their support on our collaborations.

References

Egan et al. (2018). Techniques to Enhance Assessment and Reporting of Pest Damages Estimated with Aerial Detection Surveys. R1-18 Report in Review. Missoula, MT: Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Forest Health Protection. 25 p.

Northern Region Geospatial Group (NRGG). 2016. Cumulative Analysis Tool. Users Report: NRGG UG R01 Cumulative Analysis Tool 11 28 2016 v1.
(T:\FS\Reference\GIS\r01\Data\FHP\CumulativeMortalityToolbox\)

Appendices

Appendix A

Cumulative Area Surveyed Map

Product Importance: These geospatial data represent historical aerial detection survey (ADS) coverage spanning 1991-2015. This serves as an area surveyed disclaimer to be used in conjunction with cumulative impact maps. These maps are useful to identify locations where the dataset quantity varies by number of years of flight data. Areas with limited coverage (<12 years; 0-25% and 26-49%) should be noted when evaluating the model outputs (cumulative impacts maps).

Product Description: This product is an output of the ADS survey data. It represents historical aerial detection survey coverage as fly and no fly areas. Not every acre is surveyed during each year's annual insect and disease aerial detection flights. These maps illustrate variation in representation and assist in explaining the inherent strengths and weaknesses of the Region 4 cumulative impact maps. The severity classes represent total years of coverage.

This product includes the following attributes for aerial detection survey flights spanning 1991 – 2015:

Years Surveyed: Coverage of aerial detection survey flights and subsequent dataset based on number of years a location was surveyed between 1991 and 2015. Less than 50% coverage represents areas with less than 12 years of data, and >50% coverage represents areas with more than 12 years of data. Areas with 0-25% have 0-6 years of data; 26-49% have 7-12 years of data; 50-74% have 13-19 years of data and >75% have 20-25 years of data.

Data Source: Data was collected by the USDA Forest Service, Forest Health Protection, along with State and other partnering agencies, during annual insect and disease aerial surveys. Aerial detection data can be found at: https://www.fs.usda.gov/detail/r4/forest-grasslandhealth/?cid=stelprdb5366459

The layer files are located here:
T:\FS\Reference\GIS\r04\LayerFile\R04.

How to Use: This product is best used in conjunction with the cumulative mortality tool and outputs. The two attached fly-no fly maps serve as background information on the historical areas of coverage by aerial detection survey in Region 4. Many variations in flight data exist throughout the region and this should be taken into consideration when using the cumulative impact products. Areas with limited coverage have less data than those areas with higher levels of coverage data. The amount of data available to be used in the tool will affect the quality of products.

Appropriate Use: Include these maps as background information when describing cumulative impact maps and products. This information can assist in creating display maps and footprint summary statistics for larger project areas, sub watersheds, and/or greater spatial scales such as at Forest/State/County levels. This product can also provide additional information on areas that have less historical coverage data. This may inform future requests for ADS survey locations. Efforts that may benefit from this product include: Forest Plan revisions and planning efforts, Farm Bill authority projects, field-level management projects, and recreation and vegetation management.

Inappropriate Use: Representing this product as anything beyond best-available estimations of historical ADS coverage and/or using this product as a replacement for field-level surveys and data.

Appendix B

Douglas-fir Beetle Cumulative Impact Estimation

Product Importance: These geospatial data represent best-available forest health monitoring estimations of cumulative tree mortality caused exclusively by Douglas-fir beetle (DFB) spanning 1991-2015. These estimates illustrate historical cumulative impacts from DFB. These estimates are useful to identify DFB impacted locations.

Product Description: This product is an output of the USDA Forest Service Region 1 Cumulative Impact Tool which utilizes ADS survey data. It represents a conservative estimate of historical DFB impacts. Ground and satellite remote sensing validation of ADS data indicate mortality levels are generally underestimated. In addition, not every forested acre within Region 4 is surveyed during annual insect and disease aerial detection flights. These maps do not illustrate stand conditions, and therefore differences in impacts across mixed conifer types vary across the region. These maps do not illustrate stand conditions, and therefore differences in impacts across mixed conifer forests vary. The severity classes represent levels of cumulative mortality aggregated through time.

This product includes the following attributes for DFB cause tree mortality spanning 1991 – 2015:

DFB_TPA1991_2015: Cumulative trees per acre within given spatial area.

Acres_1991_2015: Acres for polygons unioned.

NoTrees_1991_2015: Cumulative number of trees within polygons that were unioned over the range depicted.

DFB_Severity: Qualitative severity class estimating impact based on cumulative trees per polygon. 1 = low (>0 - 500 trees per polygon); 2= moderate (500-1000 tree per polygon); 3 = high (>1000)

TreesPerPolygon: Cumulative number of trees per polygon within given spatial area that were unioned over the range depicted.

Area surveyed disclaimer: Data should be used in conjunction with the ADS survey boundaries for year range depicted. See cumulative fly-no fly map for 1991-2015 (Appendix A).

Data Source: USDA Forest Service, Forest Health Protection, along with State and other partnering agencies collected, this data during annual insect and disease aerial surveys. Aerial detection data can be found at: https://www.fs.usda.gov/detail/r4/forest-grasslandhealth/?cid=stelprdb5366459

The layer files are located here:
T:\FS\Reference\GIS\r04\LayerFile\R04.

How to Use: This product is best used at broad spatial scales to identify general locations that are estimated to have impacts from DFB-caused tree mortality. However, it should not replace field surveys for validation or refinement of damage estimates and treatment recommendations.

Appropriate Use: Includes creating display maps and footprint summary statistics for larger project areas, sub watersheds, and/or similar spatial scales such as at Forest/State/County levels. This product can also provide potential field locations for further evaluation where DFB activity is likely interfering with management objectives. Efforts that may benefit from this product include: Forest Plan revisions and planning efforts, Farm Bill authority projects, field-level management projects, and recreation and vegetation management. Trend analysis at sub watershed or greater spatial scales is reasonable to compare different areas or time periods with the index statistic in yearly or cumulative renditions. See Table 1 for guidance on clipping and further geoprocessing. Please note that previous severity classes should be maintained despite changes that may result from clipping.

Inappropriate Use: Representing this product as anything beyond best-available estimations and/or using this product as a replacement for field-level surveys and data.

Appendix C

Mountain Pine Beetle Cumulative Impact Estimation

Product Importance: These geospatial data represent best-available forest health monitoring estimations of historical cumulative tree mortality caused exclusively by mountain pine beetle (MPB) spanning 1991-2015. These estimates are useful to identify MPB impacted locations.

Product Description: This product is an output of the USDA Forest Service Region 1 Cumulative Impact Tool which utilizes ADS survey data. It represents a conservative estimate of historical MPB impacts to all hosts, but primarily lodgepole pine, limber pine, and whitebark pine in Region 4. Ground and satellite remote sensing validation of ADS data indicate mortality levels are generally underestimated and not every acre is surveyed during each year's annual insect and disease aerial detection flights. These maps do not illustrate stand conditions, and therefore differences in impacts across the region and host types vary. The severity classes represent levels of cumulative mortality aggregated through time.

This product includes the following attributes for MPB cause tree mortality spanning 1991 – 2015:

MPB_TPA1991_2015: Cumulative trees per acre within given spatial area.

Acres_1991_2015: Acres for polygons unioned.

NoTrees_1991_2015: Cumulative number of trees within polygons that were unioned over the range depicted.

MPB_Severity: Qualitative severity class estimating impact based on cumulative trees/acre. 1 = low (>0 -<10 cumulative trees/acre); 2 = moderate (10-30 trees/acre); 3 = high (>30 trees/acre)

Area surveyed disclaimer: Data should be used in conjunction with the ADS survey boundaries for year range depicted. See cumulative fly-no fly map for 1991-2015 (Appendix A).

Data Source: Data was collected by the USDA Forest Service, Forest Health Protection, along with State and other Partnering agencies, during annual insect and disease aerial surveys. Aerial detection data can be found at: https://www.fs.usda.gov/detail/r4/forest-grasslandhealth/?cid=stelprdb5366459

The layer files are located here:
T:\FS\Reference\GIS\r04\LayerFile\R04.

How to Use: This product is best used at broad spatial scales to identify general locations that are estimated to have impacts from MPB-caused tree mortality. However, it should not replace field surveys for validation or refinement of damage estimates and treatment recommendations.

Appropriate Use: Includes creating display maps and footprint summary statistics for larger project areas, sub watersheds, and/or greater spatial scales such as at Forest/State/County levels. This product can also provide potential field locations for further evaluation where MPB activity may be interfering with management objectives. Efforts that may benefit from this product include: Forest Plan revisions and planning efforts, Farm Bill authority projects, field-

level management projects, and recreation and vegetation management. Trend analysis at sub watershed or greater spatial scales is reasonable to compare different areas or time periods with the index statistic in yearly or cumulative renditions.

Inappropriate Use: Representing this product as anything beyond best-available estimations and/or using this product as a replacement for field-level surveys and data.

Appendix D

Subalpine fir Mortality Complex Cumulative Impact Estimation

Product Importance: These geospatial data represent best-available forest health monitoring estimations of historical cumulative mortality caused by agents commonly associated with subalpine fir mortality complex (SAFMC) spanning 1991-2015, those include but are not limited to bark beetles, borers, stem diseases, and root diseases. These estimates are useful to identify SAFMC impacted locations.

Product Description: This product is an output of the USDA Forest Service Region 1 Cumulative Impact Tool which utilizes aerial detection survey (ADS) data. It represents a conservative estimate of historical SAFMC impacts. Ground and satellite remote sensing validation of ADS data indicate mortality levels are generally underestimated and not every acre is surveyed during each year's annual insect and disease aerial detection flights. These maps do not illustrate stand conditions, and therefore differences in impacts across the region vary.

This product includes the following attributes for SAFMC-caused tree mortality spanning 1991 – 2015:

SAFMC_TPA1991_2015: Cumulative trees per acre within given spatial area.

Acres_1991_2015: Acres for polygons unioned.

NoTrees_1991_2015: Cumulative number of trees within polygons that were unioned over the range depicted.

Note: Severity class was not added, due to vast differences across the region in regards to stand conditions.

Area surveyed disclaimer: Data should be used in conjunction with the ADS survey boundaries for year range depicted. See cumulative fly-no fly map for 1991-2015 (Appendix A).

Data Source: Data was collected by the USDA Forest Service, Forest Health Protection, along with State and other partnering agencies, during annual insect and disease aerial surveys. Aerial detection data can be found at: https://www.fs.usda.gov/detail/r4/forest-grasslandhealth/?cid=stelprdb5366459

The layer files are located here:
T:\FS\Reference\GIS\r04\LayerFile\R04.

How to Use: This product is best used at broad spatial scales to identify general locations that are estimated to have impacts from SAFMC-caused tree mortality. However, it should not replace field surveys for validation or refinement of damage estimates and treatment recommendations.

Appropriate Use: Includes creating display maps and footprint summary statistics for larger project areas, sub watersheds, and/or greater spatial scales such as at Forest/State/County levels. This product can also provide potential field locations for further evaluation where SAFMC activity may be interfering with management objectives. Efforts that may benefit from this product include: Forest Plan revisions and planning efforts, Farm Bill authority projects,

field-level management projects, and recreation and vegetation management. Trend analysis at sub watershed or greater spatial scales is reasonable to compare different areas or time periods with the index statistic in yearly or cumulative renditions.

Inappropriate Use: Representing this product as anything beyond best-available estimations and/or using this product as a replacement for field-level surveys and data.

Appendix E

Spruce Beetle Cumulative Impact Estimation

Product Importance: These geospatial data represent best-available forest health monitoring estimations of cumulative tree mortality caused exclusively by spruce beetle (SB) spanning 1991-2015. These estimates illustrate historical cumulative impacts from SB. These products are useful to identify locations of past SB activity.

Product Description: This product is an output of the USDA Forest Service Region 1 Cumulative Impact Tool which utilizes ADS survey data. It represents a conservative estimate of historical SB impacts. Ground and satellite remote sensing validation of ADS data indicate mortality levels are generally underestimated and not every acre is surveyed during each year's annual insect and disease aerial detection flights. These maps do not illustrate stand conditions, and therefore differences in impacts across the region vary. The severity classes represent levels of cumulative mortality aggregated through time.

This product includes the following attributes for SB-caused tree mortality spanning 1991 – 2015 in Region 4:

SB_TPA1991_2015: Cumulative trees per acre within given spatial area.

Acres_1991_2015: Acres for polygons unioned.

NoTrees_1991_2015: Cumulative number of trees within polygons that were unioned over the range depicted.

SB_Severity: Qualitative severity class estimating impact based on cumulative trees per polygon. 1 = low (>0 - 500 trees per polygon); 2= moderate (500-1000 trees per polygon); 3 = high (>1000 trees per polygon)

TreesPerPolygon: Cumulative number of trees per polygon within given spatial area that were unioned over the range depicted.

Area surveyed disclaimer: Data should be used in conjunction with the ADS survey boundaries for year range depicted. See cumulative fly-no fly map for 1991-2015 (Appendix A).

Data Source: Data was collected by the USDA Forest Service, Forest Health Protection, along with State and other Partnering agencies, during annual insect and disease aerial surveys. Aerial detection data can be found at: https://www.fs.usda.gov/detail/r4/forest-grasslandhealth/?cid=stelprdb5366459

The layer files are located here:
T:\FS\Reference\GIS\r04\LayerFile\R04.

How to Use: This product is best used at broad spatial scales to identify general locations that are estimated to have experienced impacts from SB-caused tree mortality. However, it should not replace field surveys for validation or refinement of damage estimates and treatment recommendations.

Appropriate Use: Includes creating display maps and footprint summary statistics for larger project areas, sub watersheds, and/or greater spatial scales such as at Forest/State/County levels. This product can also provide potential field locations for further evaluation where SB activity may be interfering with management objectives. Efforts that may benefit from this product include: Forest Plan revisions and planning efforts, Farm Bill authority projects, field-level management projects, and recreation and vegetation management. Trend analysis at sub watershed or greater spatial scales is reasonable to compare different areas or time periods with the index statistic in yearly or cumulative renditions. See Table 1 for guidance on clipping and further geoprocessing. Please note that previous severity classes should be maintained despite changes that may result from clipping.

Inappropriate Use: Representing this product as anything beyond best-available estimations and/or using this product as a replacement for field-level surveys and data.

Appendix F

Western Pine Beetle Cumulative Impact Estimation

Product Importance: These geospatial data represent best-available forest health monitoring estimations of cumulative historical tree mortality caused exclusively by western pine beetle (WPB) spanning 1991-2015 for ponderosa pine. These estimates are useful to identify locations of past WPB activity.

Product Description: This product is an output of the USDA Forest Service Region 1 Cumulative Impact Tool which utilizes ADS survey data. It represents a conservative estimate of WPB impact. Ground and satellite remote sensing validation of ADS data indicate mortality levels are generally underestimated and not every acre is surveyed during each year's annual insect and disease aerial detection flights. These maps do not illustrate stand conditions, and therefore differences in impacts across the region vary.

This product includes the following attributes for WPB-caused tree mortality spanning 1991 – 2015:

WPB_TPA1991_2015: Cumulative trees per acre within given spatial area.

Acres_1991_2015: Acres for polygons unioned.

NoTrees_1991_2015: Cumulative number of trees within polygons that were unioned over the range depicted.

Note: Severity class was not added, due to vast differences across the region in regards to mixed conifer stand conditions.

Area surveyed disclaimer: Data should be used in conjunction with the ADS survey boundaries for year range depicted. See cumulative fly-no fly map for 1991-2015 (Appendix A).

Data Source: Data was collected by the USDA Forest Service, Forest Health Protection, along with State and other Partnering agencies, during annual insect and disease aerial surveys. Aerial detection data can be found at: https://www.fs.usda.gov/detail/r4/forest-grasslandhealth/?cid=stelprdb5366459

The layer files are located here:
T:\FS\Reference\GIS\r04\LayerFile\R04.

How to Use: This product is best used at broad spatial scales to identify general locations that are estimated to have impacts from WPB-caused tree mortality. However, it should not replace field surveys for validation or refinement of damage estimates and treatment recommendations.

Appropriate Use: Includes creating display maps and footprint summary statistics for larger project areas, sub watersheds, and/or greater spatial scales such as at Forest/State/County levels. This product can also provide potential field locations for further evaluation where WPB activity may be interfering with management objectives. Efforts that may benefit from this product include: Forest Plan revisions and planning efforts, Farm Bill authority projects, field-level management projects, and recreation and vegetation management. Trend analysis at sub

watershed or greater spatial scales is reasonable to compare different areas or time periods with the index statistic in yearly or cumulative renditions.

Inappropriate Use: Representing this product as anything beyond best-available estimations and/or using this product as a replacement for field-level surveys and data.

Appendix G

Western Spruce Budworm Cumulative Impact Estimation

Product Importance: These geospatial data represent best-available forest health monitoring estimations of historical cumulative impacts caused by western spruce budworm (WSBW) defoliation spanning 1991-2015. These estimates are useful to identify locations of past WSBW activity.

Product Description: This product is an output of the USDA Forest Service Region 1 Cumulative Impact Tool which utilizes ADS survey data. It represents a conservative estimate of WSBW impac t. Ground and satellite remote sensing validation of ADS data indicate defoliation levels are generally underestimated and not every acre is surveyed during each year's annual insect and disease aerial detection flights. These maps do not illustrate stand conditions, and therefore differences in impacts across the region vary. Please note that impacts to regeneration size class hosts in the understory are rarely captured by aerial detection survey and this limits confidence in the cumulative impact tools' estimates for western spruce budworm.

This product includes the following attributes for WSBW defoliation spanning 1991 – 2015:

SBW_1991_2015: Cumulative defoliation severity based on ADS survey data attribute (SEVERITY1, SEVERITY2, SEVERITY3) which indicates light, moderate, and heavy defoliation, respectively.

WSBW_IND_DRSCRIP: Qualitative description estimating impact 1 = low (> 0 - < 1); 2 = moderate (>= 1 and < 3); 3 = high (>= 3) based on cumulative defoliation severity.

ACRES_1991_2015: Acres for polygons unioned.

S_ACRES_1991_2015: Weighted acres using most severe defoliation category as baseline (acres from high * 1.0, acres from moderate * 0.5, acres from low * 0.1). This weighted acreage represents a conservative estimate of WSBW overstory impacts in terms of level of crown defoliation and growth/vigor reductions as represented by low, moderate, and high classes. These classes can approximate crown dieback as well; however, host trees can re-foliate following budworm activity if buds remain viable. As such, there is reduced confidence in this estimation as surveys do not detect foliage re-flushing or if annual surveys occurred before peak defoliation for a particular year.

Area surveyed disclaimer: Data should be used in conjunction with the ADS survey boundaries for year range depicted. See cumulative fly-no fly map for 1991-2015 (Appendix A).

Data Source: Data was collected by the USDA Forest Service, Forest Health Protection, along with State and other partnering agencies, during annual insect and disease aerial surveys. Aerial detection data can be found at: https://www.fs.usda.gov/detail/r4/forest-grasslandhealth/?cid=stelprdb5366459

The layer files are located here:
T:\FS\Reference\GIS\r04\LayerFile\R04.

How to Use: This product is best used at broad spatial scales to identify general locations that were estimated to have substantial budworm impacts. This product may also be used for project-level display purposes to represent general conditions; however, it should not replace field surveys for validation or refinement of damage estimates.

Appropriate Use: Includes creating display maps and footprint summary statistics for larger project areas, sub watersheds, and/or greater spatial scales such as at Forest/State/County levels. This product can also provide potential field locations for further evaluation where WSBW activity is likely interfering with management objectives. Efforts that may benefit from this product include: Forest Plan revisions and planning efforts, Farm Bill authority projects, field-level management projects, and recreation and vegetation management. Trend analysis at sub watershed or greater spatial scales is reasonable to compare different areas or time periods with the index statistic in yearly or cumulative renditions.

Inappropriate Use: Representing this product as anything beyond best-available estimations and/or using this product as a replacement for field-level surveys and data.